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Cranial Variation in Prehistoric Human Skeletal Remains From the Marianas

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ABSTRACT Nonmetric cranial variation and facial flatness of the Pacific and circum-Pacific populations are investigated. The peoples of the Marianas, eastern Polynesia and Hawaii form a cluster and show affinities in terms of nonmetric cranial variation with the Southeast and East Asians rather than with the Jomon-Ainu, a view which is widely supported by others. Facial flatness analysis also indicates that Polynesians have different patterns of facial prominence as compared with the Jomon-Ainu. These results increase the difficulty of accepting the Jomon-Pacific cluster proposed by Brace and his coworkers. Although genetic and nonmetric cranial variation reveal relatively close relationships, the Mariana skeletons are markedly different in facial flatness and limb bone morphology from those of Polynesians. Am J Phys Anthropol 104:399–410, 1997.

People originating in Asia are believed to have been the first to colonize the Pacific Islands and the Americas. Many scholars have tried to resolve the time, method, and routes of migration to the Pacific (Pietrusewsky, 1971, 1984, 1990a,b; Howells, 1973, 1979, 1989, 1990; Brace and Hinton, 1981; Brace et al., 1990; Omoto, 1985; Katayama, 1987, 1988, 1990; Bellwood, 1989; Turner, 1989, 1990; Hill et al., 1989; Serjeantson, 1989; Gao and Serjeantson, 1991, 1992). Archaeologists consider the bearers of the Lapita Cultural Complex to be the ancestors of the Polynesians (Bellwood, 1989). However, the human skeletal remains associated with the Lapita Cultural Complex are few and fragmentary (Pietrusewsky, 1989).

Craniometric variation in Micronesia was recently investigated by Pietrusewsky (1990a). We have evaluated the population affinities of human skeletal remains from the Marianas and Hawaii with other circum-Pacific populations excepting groups from southeast Asia (Ishida, 1992, 1993; Ishida and Dodo, 1993). In this paper, we compare skeletal remains from the Marianas with those of circum-Pacific populations including early and modern Thailanders. Through analyses of nonmetric cranial variation and facial flatness we seek to determine whether the Pacific peoples are similar to the southeast Asians or the Jomon-Ainu.

MATERIALS AND METHODS

This study includes specimens representing 13 groups: Marianas, Hawaiians, eastern Polynesians, modern Thailanders, early Thailanders, Jomon, Doigahama Yayoi, modern Japanese, Hokkaido Ainu, Mongolians, Alaskan Eskimo, northern Chinese and On-

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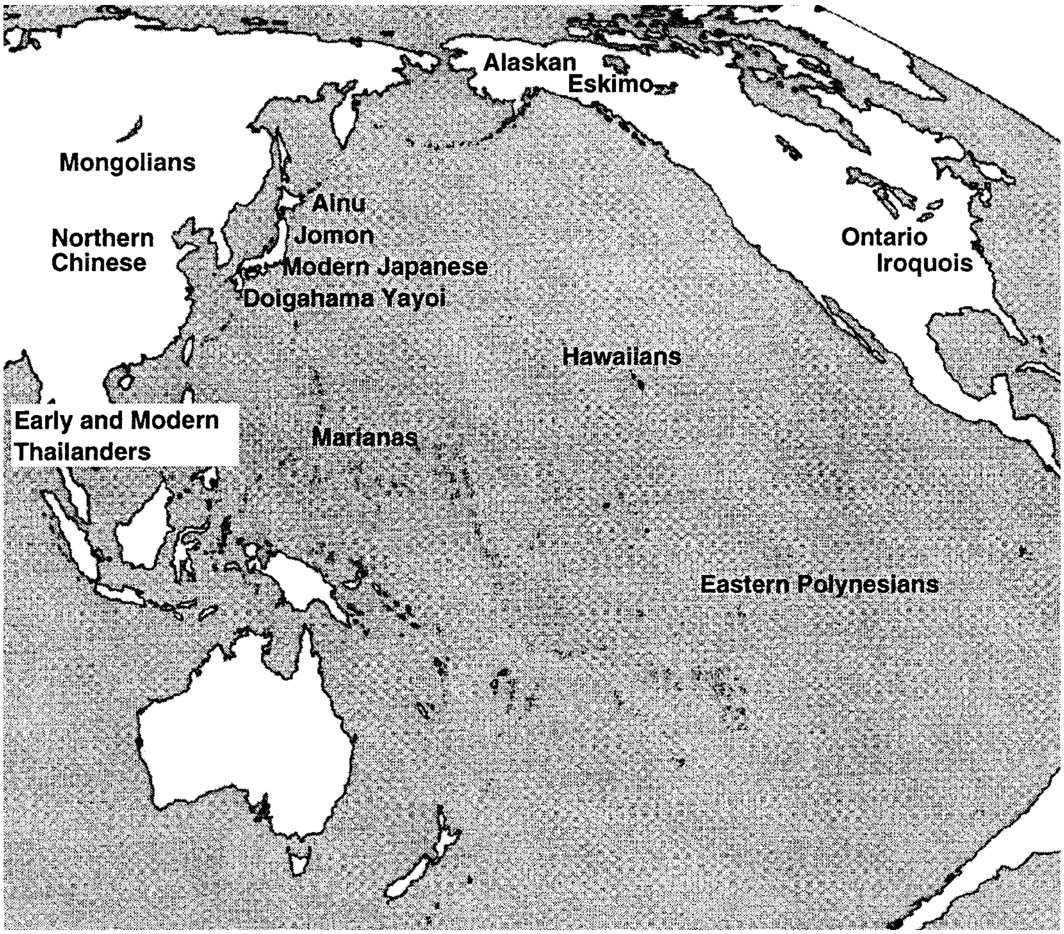

Fig. 1. Location of 13 Pacific and circum-Pacific populations.

tario Iroquois (Fig. 1). Table 1 summarizes the samples used and the institutions where they are housed.

The skeletal remains from the Marianas were mainly collected by J.C. Thompson and H.G. Hornbostel in 1922–23. The specimens are believed to date to the pre-Spanish or early post-Spanish epochs. These latter consist of 92 male and 77 female adult skulls from Guam, six male and two female adult skulls from Saipan, and 11 male and four female adult skulls from Tinian Island. The cranial samples from Hawaii are from the Mokapu Peninsula on Oahu. The sample of the eastern Polynesians is from the Society, Marquesas, and Tuamotu Islands.

The skeletal collections of modern Thailanders are from inhabitants around Bangkok. The early Thailand sample consists of material from the Ban Chiang, Ban Kao and the Ban Na Di sites in Thailand (Pietrusewsky, 1997a).

Four series consisting of Jomon, Doigahama Yayoi, modern Japanese and Hokkaido Ainu, respectively, are from the Japanese archipelago. The skeletal series of the Doigahama Yayoi are generally believed to represent immigrants from the Asian continent (Nakahashi, 1993).

Twenty-two nonmetric cranial traits were examined, by the second author, for presence or absence following the criteria of Dodo (1974, 1986a, 1987), a procedure which eliminates interobserver error. Estimates of biological distances were carried out with Konigsberg's method (1990) using nonmet-

TABLE 1. Materials used

Populations	Collections	Sources
Marianas	BM	Dodo (1986d), Ishida and Dodo (1993)
Hawaiians	BM	Ishida (1993), Ishida and Dodo (1993)
Eastern Polynesians	BM	Present study
Modern Thailanders	MU	Dodo (1994), present study
Early Thailanders	MU, UH	Present study
Jomon	UT, NSMT, TU, SMU	Dodo and Ishida (1990), Yamaguchi (1980)
Doigahama Yayoi	KSU	Doi and Tanaka (1987), Dodo and Ishida (1990)
Modern Japanese	CU, TU	Yamaguchi (1973), Dodo and Ishida (1987)
Hokkaido Ainu	UT, SMU	Yamaguchi (1973), Dodo and Ishida (1987)
Mongolians	NMNH	Dodo (1986d), Dodo and Ishida (1987)
Alaskan Eskimo	NMNH	Dodo (1986d), Dodo and Ishida (1987)
Northern Chinese	UT, KTU	Ishida (1993), Ishida and Dodo (1993)
Ontario Iroquois	UTO	Dodo (1986d), Dodo and Ishida (1987)

BM, B.P. Bishop Museum, Honolulu; MU, Mahidol University, Bangkok; UH, University of Hawaii, Honolulu; UT, University of Tokyo, Tokyo; NSMT, National Science Museum, Tokyo; TU, Tohoku University, Sendai; SMU, Sapporo Medical University, Sapporo; KSU, Kyushu University, Fukuoka; CU, Chiba University, Chiba; NMNH, National Museum of Natural History, Smithsonian Institution, Washington, D.C.; KTU, Kyoto University, Kyoto; UTO, University of Toronto, Toronto.

ric traits. This approach extends the method of Mahalanobis' distances to nonmetric traits using a tetracholic correlation matrix. The computer program, which was provided by Konigsberg, was extended for use on a Unix operating system. Because the early Thailanders are too poorly preserved to yield a sufficient number, we eliminated this series from nonmetric trait distance analysis.

Facial flatness was measured as described by Yamaguchi (1973). Biological distances between the 13 populations were estimated by Mahalanobis' Generalized Distances (D^2) using the pooled variance-covariance matrix obtained from the measurements of 260 complete male crania to avoid distortions due to intertrait correlations (Sneath and Sokal, 1973; Mizoguchi, 1988).

Classical multidimensional scaling was applied to the distance matrix using S language (Becker et al., 1988) to represent two-dimensional relationships between the samples. The neighbor-joining method (Saitou and Nei, 1987) was also carried out based on the distance matrix.

NONMETRIC CRANIAL VARIATION

Our studies of Japanese populations have demonstrated that our battery of nonmetric cranial traits are relatively immune to environmental factors (Dodo and Ishida, 1990). For instance, most of the nonmetric cranial traits show no significant difference in frequency during the last 600 years, from the early medieval to the recent time in Japan. Reliable documentation indicates no significant gene inflow from continental Asia or elsewhere into the main islands of Japan during these periods. On the other hand, the cranial vault varied in shape from dolichocranic to brachicranic during this same time period (Dodo and Ishida, 1990). Such stability of nonmetric traits, in contrast to metric ones, seems to validate the former's use in ethnogenetic studies (Ishida and Dodo, 1996), even though the genetic backgrounds of those traits remains to be elucidated.

Tables 2(a) and 2(b) present the frequencies of occurrence of 22 nonmetric cranial traits per skull in the 12 populations from the Marianas, Polynesia and circum-Pacific regions. The incidence of the supraorbital foramen in the Mariana series is intermediate between those of the Jomon-Ainu and the other populations, while the low frequency of the transverse zygomatic suture vestige is comparable only to that in the Polynesians. The high incidence of the tympanic dehiscence in the Mariana series is unlike that observed in Polynesians but is similar to that recorded in the continental Asians and North Americans. Traits which were found to be significantly different from the Mariana series include eight traits in the Hawaiians, three in the eastern Polynesians, four in the modern Thailanders, nine in the Jomon, eight in the Doigahama Yayoi, nine in the modern Japanese, nine in the Hokkaido Ainu, nine in the Mongolians, nine in the Alaskan Eskimo, five in the Northern Chinese, and 12 in the Ontario Iroquois series.

TABLE 2(a). Skull incidences of 22 nonmetric cranial traits in 12 cranial samples from the circum-Pacific regions

Traits	Marianas		Hawaiians		Eastern Polynesians		Modern Thailanders		Jomon		Doigahama Yayoi	
	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*
1. Metopism	1/170	0.006	0/203	(0.001)	0/45	(0.006)	3/131	0.023	24/159	0.151**	10/126	0.079**
2. Supraorbital nerve groove	11/159	0.069	46/196	0.235**	12/44	0.273**	43/127	0.339**	20/117	0.171*	16/97	0.165*
3. Supraorbital foramen	55/164	0.335	129/202	0.639**	31/44	0.705**	76/131	0.580**	23/124	0.185**	51/96	0.531**
4. Ossicle at the lambda	24/156	0.154	6/195	0.031**	2/43	0.047	11/119	0.092	7/156	0.045**	23/128	0.180
5. Biasterionic suture	23/155	0.148	31/203	0.153	3/41	0.073	15/129	0.116	52/138	0.377**	22/133	0.165
6. Asterionic bone	17/146	0.116	25/202	0.124	7/41	0.171	26/128	0.203	16/113	0.142	28/116	0.241*
7. Occipito-mastoid wormians	26/133	0.195	56/202	0.277	11/37	0.297	28/123	0.228	11/66	0.167	40/91	0.440**
8. Parietal notch bone	37/154	0.240	16/202	0.079**	6/40	0.150	27/125	0.216	18/88	0.205	38/109	0.349
9. Condylar canal patent	108/116	0.931	167/199	0.839*	29/34	0.853	110/128	0.859	42/42	(0.994)	46/55	0.836
10. Precondylar tubercle	17/114	0.149	53/196	0.270*	8/38	0.211	27/130	0.208	8/80	0.100	8/76	0.105
11. Paracondylar process	3/97	0.031	4/194	0.021	3/28	0.107	3/125	0.024	2/15	0.133	1/41	0.024
12. Hypoglossal canal bridging	19/113	0.168	26/201	0.129	6/35	0.171	18/130	0.138	28/84	0.333*	13/90	0.144
13. Tympanic dehiscence	76/152	0.500	19/203	0.094**	12/42	0.286*	60/130	0.461	43/127	0.339**	27/127	0.213**
14. Ovale-spinosum confluence	10/114	0.088	7/199	0.035*	1/39	0.026	3/131	0.023*	2/44	0.045	1/77	0.013
15. Foramen of Vesalius	49/117	0.419	71/195	0.364	14/40	0.350	64/131	0.489	31/55	0.564	23/68	0.338
16. Pterygo-spinous foramen	13/120	0.108	12/202	0.059	2/40	0.050	4/131	0.031*	3/65	0.046	2/91	0.022*
17. Medial palatine canal	3/130	0.023	11/201	0.055	1/38	0.026	6/131	0.046	15/80	0.188**	4/84	0.048
18. Transverse zygomatic suture vestige	1/98	0.010	2/162	0.012	0/32	(0.008)	8/125	0.064	31/68	0.456**	11/58	0.190**
19. Clinoid bridging	2/83	0.024	9/182	0.049	1/38	0.026	13/127	0.102	0/10	(0.025)	0/24	(0.010)
20. Mylohyoid bridging	13/121	0.107	19/185	0.103	1/35	0.029	9/118	0.076	23/112	0.205	9/94	0.096
21. Jugular foramen bridging	8/109	0.073	14/199	0.070	2/35	0.057	20/131	0.153	1/34	0.029	12/68	0.176
22. Sagittal sinus groove flexes left	22/154	0.143	27/203	0.133	7/42	0.167	21/129	0.163	15/127	0.118	21/123	0.171

TABLE 2(b). Skull incidences of 22 nonmetric cranial traits in 12 cranial samples from the circum-Pacific regions

Traits	Modern Japanese		Hokkaido Ainu		Mongolians		Alaskan Eskimo		Northern Chinese		Ontario Iroquois	
	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*	A/O	*P*
1. Metopism	16/180	0.089**	6/184	0.033	16/178	0.090**	1/200	0.005	11/167	0.066**	0/247	(0.001)
2. Supraorbital nerve groove	55/177	0.311**	17/114	0.149*	54/177	0.305**	39/198	0.197**	43/159	0.270**	98/207	0.473**
3. Supraorbital foramen	99/180	0.550**	41/170	0.241	108/177	0.610**	157/200	0.785**	103/167	0.617**	151/211	0.716**
4. Ossicle at the lambda	7/174	0.040**	1/186	0.005**	29/173	0.168	17/189	0.090	21/155	0.135	47/232	0.203
5. Biasterionic suture	28/176	0.159	37/182	0.203	48/177	0.271**	56/200	0.280**	27/165	0.164	6/219	0.027*
6. Asterionic bone	20/172	0.116	31/177	0.175	26/176	0.148	29/199	0.146	22/163	0.135	48/180	0.267**
7. Occipito-mastoid wormians	31/179	0.173	37/177	0.209	36/167	0.216	49/174	0.282	27/157	0.172	47/157	0.299*
8. Parietal notch bone	62/172	0.360*	41/175	0.234	32/175	0.183	55/198	0.278	43/159	0.270	34/171	0.199
9. Condylar canal patent	153/178	0.860	159/175	0.909	146/178	0.820*	188/198	0.949	140/162	0.864	155/159	0.975
10. Precondylar tubercle	16/178	0.090	13/165	0.079	31/174	0.178	15/198	0.076*	20/164	0.122	5/183	0.027*
11. Paracondylar process	9/168	0.054	13/126	0.103	4/165	0.024	3/159	0.019	4/153	0.026	3/104	0.029
12. Hypoglossal canal bridging	26/180	0.144	63/178	0.354**	28/176	0.159	51/199	0.256	35/166	0.211	61/187	0.326*
13. Tympanic dehiscence	64/179	0.358*	37/177	0.209**	67/178	0.376*	83/200	0.415	76/165	0.461	100/185	0.541
14. Ovale-spinosum confluence	3/180	0.017**	14/169	0.083	6/177	0.034	3/200	0.015**	5/166	0.030	2/142	0.014*
15. Foramen of Vesalius	84/179	0.469	45/169	0.266**	105/178	0.590**	66/200	0.330	89/167	0.533	70/160	0.438
16. Pterygo-spinous foramen	5/179	0.028**	13/160	0.081	8/178	0.045	12/200	0.060	9/168	0.054	5/179	0.028**
17. Medial palatine canal	14/177	0.079	33/151	0.219**	5/173	0.029	7/198	0.035	9/166	0.054	3/100	0.030
18. Transverse zygomatic suture vestige	19/167	0.114**	32/96	0.333**	24/146	0.164**	22/170	0.129**	15/142	0.106**	1/33	0.030
19. Clinoid bridging	8/177	0.045	24/154	0.156**	15/177	0.085	34/198	0.172**	17/164	0.104*	48/145	0.331**
20. Mylohyoid bridging	11/177	0.062	29/137	0.212**	6/66	0.091	18/116	0.155	4/88	0.045	33/94	0.351**
21. Jugular foramen bridging	27/222	0.122	13/110	0.118	24/178	0.135	37/199	0.186*	21/165	0.127	9/156	0.058
22. Sagittal sinus groove flexes left	26/153	0.170	17/124	0.137	45/170	0.265**	45/187	0.241*	26/159	0.164	54/231	0.234*

O = number of crania actually observed; A = numbers of crania showing trait (affected); *P*, frequency of occurrence.
Figures in parentheses were calculated by 1/4N or 1 − 1/4N (Bartlett's adjustment).
Asterisks: Significantly different from the Mariana series at the * 0.05 or ** 0.01 level.

TABLE 3. Biological distances estimated based on the 22 nonmetric cranial traits

Populations	1	2	3	4	5	6	7	8	9	10	11	12
1. Marianas	0											
2. Hawaiians	5.466	0										
3. Eastern Polynesians	6.504	3.973	0									
4. Modern Thailanders	5.498	3.155	6.828	0								
5. Jomon	16.143	12.180	16.682	11.187	0							
6. Doigahama Yayoi	8.631	7.699	9.042	5.899	9.819	0						
7. Modern Japanese	5.243	5.041	5.384	3.474	7.603	2.995						
8. Hokkaido Ainu	11.529	7.706	9.304	9.663	7.066	8.351	5.769	0				
9. Mongolians	6.209	3.937	8.686	1.411	9.656	5.223	2.431	8.624	0			
10. Alaskan Eskimo	11.785	9.714	13.255	6.949	18.275	10.511	7.500	14.739	6.578	0		
11. Northern Chinese	5.692	5.013	6.978	1.682	8.570	3.825	1.267	7.948	1.468	7.579	0	
12. Ontario Iroquois	11.469	9.616	13.601	6.848	22.315	15.865	11.834	16.525	9.019	9.514	9.466	0

The biological distances for the 12 populations were based on the 22 nonmetric cranial traits. The distance matrix is given in Table 3. The Mariana series is closest to modern Japanese, Hawaiians and modern Thailanders. The groups closest to Hawaii are modern Thailanders, Mongolians and eastern Polynesians. The three Pacific populations, including eastern Polynesians, are the most distant from the Jomon-Ainu and Ontario Iroquois series. The modern Thailanders show more affinities with the northern Chinese and Mongolians than with the Marianas or Hawaiians.

Classical multidimensional scaling was applied to the distance matrix to establish two-dimensional relationships, as drawn in Figure 2. The three Pacific populations are situated in the lower right portion in the figure. Among these, the Hawaiians is closest to the continental Asian and Japanese groups, which cluster in the center of the diagram. The Jomon and Hokkaido Ainu form a cluster isolated from the other groups. Finally, the Ontario Iroquois is the most isolated series in the diagram.

The neighbor-joining method was also applied to the distance matrix to represent an unrooted tree. The results (Fig. 3), although almost the same as those obtained using the classical multidimensional scaling method, are more definitive. The east and southeast Asian populations are grouped in the center. Three distinct branches emerge from the center; the first consists of the Marianas, eastern Polynesia and Hawaii, a branch which is closest to the Asian and especially modern Thailanders; a second branch culminates in Jomon and Ainu; and a third includes an isolated North American branch.

In our previous preliminary study of nonmetric cranial variation, the Mariana series showed closer affinities with the modern Japanese than with the Ainu (Dodo, 1986b). Further, the results from wider comparisons indicated that the Mariana and Hawaiians peoples are both closer to the east Asian than to the Jomon-Ainu or to the arctic peoples (Ishida and Dodo, 1993).

Recently the suggestion has been made by Brace and colleagues that the Jomon-Ainu are related to the Pacific Islanders (Brace et al., 1990; Li et al., 1992; Brace and Tracer, 1992). Through analyses of tooth size and cranial measurements, of which two-thirds relate to the nasal skeleton, Brace claims

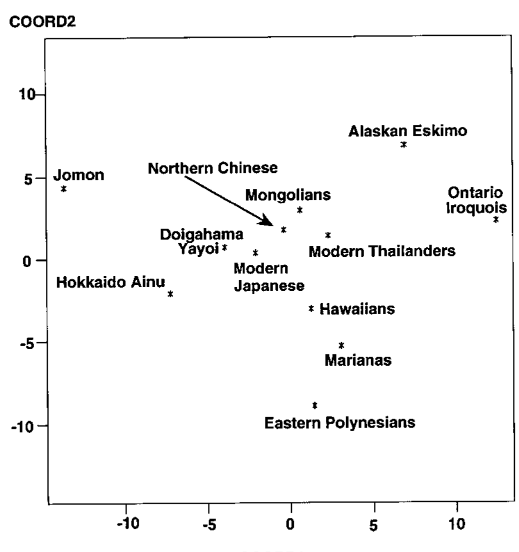

Fig. 2. Classical multidimensional scaling of 12 populations based on the distance matrix obtained from the 22 nonmetric cranial traits listed in Table 3.

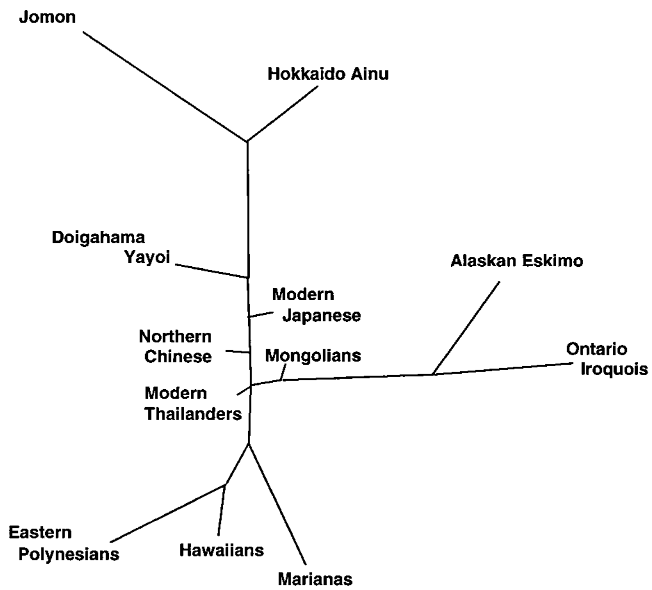

Fig. 3. An unrooted tree of the 12 population samples by the neighbor-joining method based on the distance matrix obtained from the 22 nonmetric cranial traits.

that there is a close relationship between the Jomon-Ainu and the Pacific peoples, which he calls “the Jomon-Pacific cluster,” and that there is a good possibility that the Jomon people had migrated into the islands of the Pacific. Katayama (1990) also proposes a “Proto-Oceanic” population, represented by the Jomon people, who dispersed into the Pacific region.

However, the results of many other analyses of dental morphology and other craniometric measurements have shown few or no direct relationships between the Jomon-Ainu and Pacific populations (Turner, 1989, 1990; Pietrusewsky, 1992; Hanihara, 1992, 1993). Genetic studies have also indicated affinities of the Pacific peoples not with the Ainu but with the mainland and insular southeast Asians (Cavalli-Sforza et al., 1988; Harihara et al., 1992; Nei and Roychoudhury, 1993). The present study, based on nonmetric cranial variation, suggests that the Marianas and the two Polynesian samples are derived from a continental Asian ancestral population close to that from which the modern Thailanders derived. The affinity is not from the Jomon-Ainu. The present evidence reinforces our previous interpretation that the ancestors of the Pacific peoples, who had little affinity in terms of nonmetric cranial variation to the Jomon, dispersed from southeast Asia into the Pacific Islands (Ishida and Dodo, 1993).

FACIAL FLATNESS

Facial flatness is one of the major characteristics of the populations originating in Asia. Many researchers have been interested in the inhabitants of Siberia because of their particularly flat facial features. Compared with Siberian peoples, other peoples collectively called “Mongoloid” have a greater variation of facial flatness (Ishida, 1992). In this section of the paper we examine facial flatness in the circum-Pacific populations, especially focusing on the Pacific peoples.

Facial flatness measurements and indices of the frontal, simotic and zygomaxillary regions are given in Tables 4–6, respectively.

The averages of the frontal indices of the Marianas, Hawaii and eastern Polynesians range from 16.0 to 17.5. The modern Thailanders have almost the same value for the index as those of the Pacific peoples, whereas the mean of the early Thailanders is as low as those of the Mongolians and Eskimos. With regard to the simotic index, the Mariana series has lower values than the Polynesians. The early inhabitants of Thailand have an unusually low value for this index due to their very flattened nasal bridges.

TABLE 4. Frontal measurements and indices of flatness

Populations	n	Chord Mean	Chord sd	Subtense Mean	Subtense sd	Index Mean	Index sd
Marianas	77	99.7	3.43	16.0	2.11	16.0	2.00
Hawaiians	83	99.5	3.45	16.2	2.11	16.2	1.98
Eastern Polynesians	21	99.7	3.82	17.5	2.04	17.5	1.74
Modern Thailanders	50	97.1	3.97	15.7	1.96	16.2	1.83
Early Thailanders	20	101.4	3.74	14.5	3.36	14.3	3.23
Jomon	28	99.6	3.25	16.4	2.41	16.5	2.41
Doigahama Yayoi	32	100.9	3.16	15.6	2.27	15.4	2.30
Modern Japanese	86	97.8	4.29	16.3	2.08	16.7	1.88
Hokkaido Ainu	68	99.5	3.64	16.9	2.13	17.0	1.91
Mongolians	97	100.7	4.27	14.7	2.22	14.5	1.95
Alaskan Eskimo	108	100.8	2.89	14.9	3.99	14.8	1.90
Northern Chinese	104	95.9	3.57	14.8	2.08	15.4	1.96
Ontario Iroquois	92	99.3	3.66	17.5	2.68	17.6	2.52

TABLE 5. Simotic measurements and indices of flatness

Populations	n	Chord Mean	Chord sd	Subtense Mean	Subtense sd	Index Mean	Index sd
Marianas	53	8.2	1.64	2.7	0.80	32.8	8.20
Hawaiians	80	7.8	1.75	3.0	1.01	38.9	12.20
Eastern Polynesians	20	7.6	1.23	3.3	0.73	43.8	9.42
Modern Thailanders	49	8.5	2.15	2.9	0.91	35.2	9.09
Early Thailanders	19	8.7	1.65	2.5	0.87	29.1	9.07
Jomon	16	10.2	1.89	4.6	0.76	45.5	8.21
Doigahama Yayoi	30	8.4	1.72	2.3	0.85	26.7	7.06
Modern Japanese	86	7.2	1.91	2.7	0.97	38.7	12.78
Hokkaido Ainu	69	8.7	1.68	3.7	0.92	43.3	12.52
Mongolians	94	7.5	1.65	3.1	1.05	41.1	12.04
Alaskan Eskimo	99	6.4	1.44	2.94	0.82	46.8	10.14
Northern Chinese	104	6.9	1.69	2.54	0.93	37.2	11.43
Ontario Iroquois	80	9.0	1.51	3.8	0.83	42.7	10.75

Simotic chord = the minimum horizontal breadth of the nasalia; simotic subtense = the minimum subtense from the median ridge of the nasalia to the simotic chord (Yamaguchi, 1973).

TABLE 6. Zygomaxillary measurements and indices of flatness

Populations	n	Chord Mean	Chord sd	Subtense Mean	Subtense sd	Index Mean	Index sd
Marianas	54	102.7	4.86	22.8	2.03	22.2	2.13
Hawaiians	75	99.7	4.28	25.0	2.43	25.1	2.59
Eastern Polynesians	20	98.4	3.46	26.2	2.95	26.6	2.59
Modern Thailanders	49	99.3	4.90	23.6	2.40	23.4	3.35
Early Thailanders	11	105.1	4.16	23.8	2.74	22.6	2.20
Jomon	11	102.8	5.98	22.9	3.22	22.2	2.90
Doigahama Yayoi	21	105.4	4.14	21.1	2.94	20.1	2.90
Modern Japanese	83	97.9	5.19	23.6	2.89	24.1	2.99
Hokkaido Ainu	51	101.4	5.54	22.7	2.02	22.5	1.90
Mongolians	89	103.7	5.30	19.9	2.66	19.3	2.53
Alaskan Eskimo	106	103.9	5.18	22.0	2.94	21.2	2.75
Northern Chinese	106	98.3	4.14	22.5	2.92	22.8	2.71
Ontario Iroquois	38	102.0	4.72	27.4	2.61	26.9	2.55

The zygomaxillary index of the Marianas is low (22.2), while the Hawaiians and eastern Polynesians have high indices.

In summary, the Mariana Islanders have moderately flat faces, whereas the Polynesians, especially eastern Polynesians, have relatively prominent faces among the Asian populations. The faces of the early Thailanders are quite flat while the flatness of the modern Thailanders is reduced.

The matrix of the Mahalanobis' Generalized Distances calculated for the 13 cranial series is presented in Table 7. The Marianas are most similar to the Doigahama Yayoi

TABLE 7. Mahalanobis' Generalized Distance matrix computed from three sets of facial flatness measurements

Populations	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Marianas	0												
2. Hawaiians	0.979	0											
3. Eastern Polynesians	2.242	0.477	0										
4. Modern Thailanders	0.937	1.031	2.176	0									
5. Early Thailanders	1.224	2.415	4.767	2.693	0								
6. Jomon	3.451	4.001	5.184	3.731	4.319	0							
7. Doigahama Yayoi	0.703	3.147	5.186	2.743	1.132	5.035							
8. Modern Japanese	1.153	0.813	1.185	0.955	4.018	5.447	3.177	0					
9. Hokkaido Ainu	0.978	1.608	2.267	1.723	3.134	1.439	2.373	1.700	0				
10. Mongolians	2.766	4.599	6.375	5.268	3.651	3.989	2.662	4.387	2.161	0			
11. Alaskan Eskimo	2.995	3.553	4.554	5.557	4.240	5.017	3.778	3.795	2.521	0.847	0		
12. Northern Chinese	1.646	1.786	2.828	1.039	4.300	5.379	3.497	0.570	2.138	3.870	3.754	0	
13. Ontario Iroquois	3.245	1.662	1.542	2.691	4.802	3.606	6.304	3.716	3.021	8.654	7.053	5.106	0

and next, to modern Thailanders. Hawaii and eastern Polynesia are close and both show similarities with modern Japanese, modern Thailanders and Ontario Iroquois. The modern Thailanders are closest to the Marianas and modern Japanese while the early Thailanders show affinities with the Doigahama Yayoi and the Marianas due to their flattened nasal bones.

Classical multidimensional scaling was applied to the matrix of the Mahalanobis' Generalized Distances given in Table 7. The results are drawn in Figure 4. The groups having more prominent faces are situated on the upper left portion in the figure and those with flatter faces are on the right side. The Mariana series is located near the center of this figure. The Hawaiians and eastern Polynesians, exhibiting less flattened faces, are located in the left portion and show little affinity with the Jomon and Ainu.

Next, the neighbor-joining method was applied to the distance matrix, as shown in Figure 5. The prehistoric early Thailanders and Doigahama Yayoi join to form a cluster, to which the Marianas attaches. The Hawai-

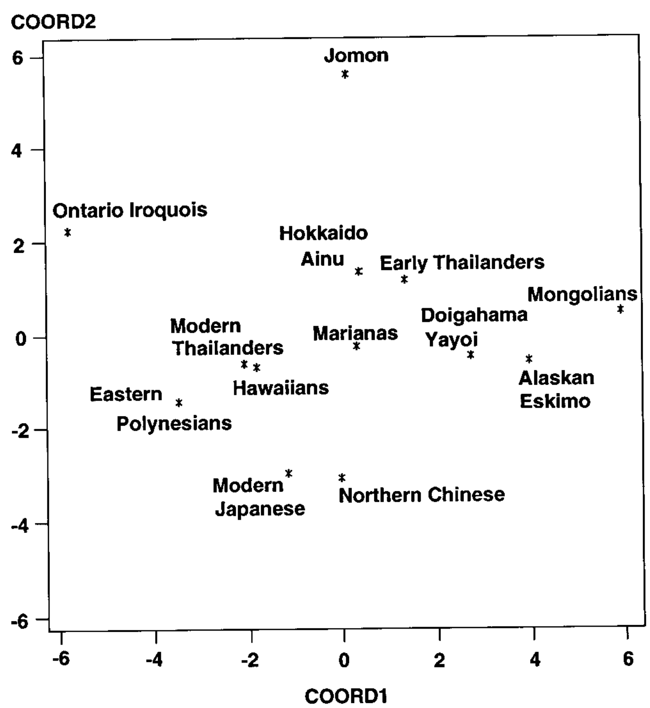

Fig. 4. Two-dimensional representation of 13 population samples by classical multidimensional scaling applied to the Mahalanobis' Distance matrix obtained from six facial flatness measurements.

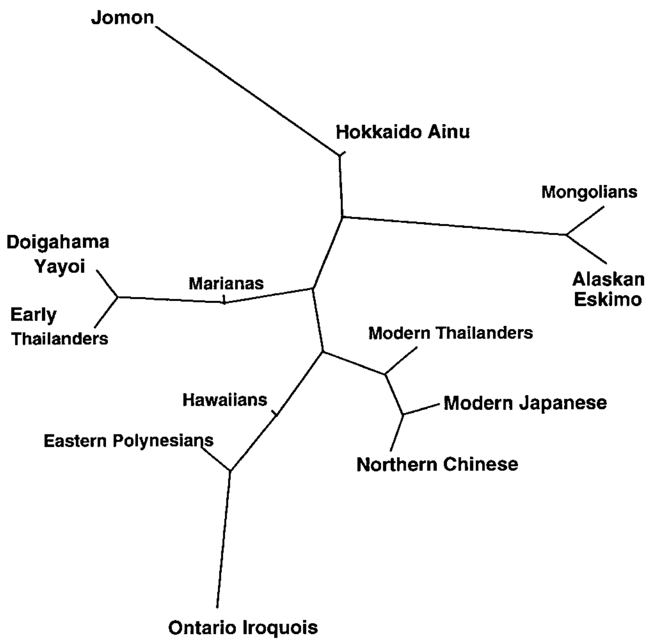

Fig. 5. A tree of the 13 population samples by the neighbor-joining method applied to the matrix of Mahalanobis' Distances obtained from the six facial flatness measurements.

ians and eastern Polynesians form a branch with the Ontario Iroquois. This latter cluster connects to a cluster consisting of the modern Thailanders, northern Chinese and modern Japanese. The Jomon and Hokkaido Ainu, related to each other, are joined to a long branch formed by the Mongolians and Alaskan Eskimos.

The results of this second analysis, based on facial flatness measures, are not as clear as the first analysis. However, to summarize the strongest results, the Jomon fall close to the Hokkaido Ainu, and the Polynesians to the Ontario Iroquois, to make two different clusters. Although both have prominent faces, the flat zygomaxillary regions of the Jomon and the Hokkaido Ainu contrast with the marked prognathism of the Polynesians and Ontario Iroquois. The Mariana Islanders are more distant from the Polynesians due to their flatter faces.

DISCUSSION AND CONCLUSION

According to these nonmetric cranial observations, the Marianas, Hawaii and Eastern Polynesians cluster closely together and seem to be derived from a southeast Asian ancestral population close to that from which the modern Thailanders derived. However, the samples from the Island southeast Asia and Melanesia must be included in future studies to elucidate the complete populational affinities of Pacific peoples.

The close relationship of the Jomon and Ainu has been indicated by analyses of craniometry, nonmetric cranial traits and dental morphology (e.g., Turner, 1976; Yamaguchi, 1982; Ossenberg, 1986; Dodo, 1986c; Ishida, 1993; Pietrusewsky, 1994). The present analysis of both nonmetric cranial traits and facial flatness measurements confirms this affinity between the Jomon and Ainu.

Brace and Tracer (1992) have argued that the Jomon-Pacific populations and American Indians group together to form an isolated cluster. Others (e.g., Pietrusewsky, 1994) have concluded that Jomon and Pacific crania are two different groups.

Although recent dental and cranial research has pointed to an origin of the Jomon-Ainu in southeast Asia (Turner, 1987, 1989, 1990; Hanihara, 1992; Matsumura, 1994), few or no direct relationships between the Jomon-Ainu and Pacific peoples have been suggested. Since the Jomon-Ainu are equally removed from not only the Pacific samples but from the modern Thailanders, no affinity between the Jomon-Ainu and southeast Asians is apparent in the present nonmetric

study. Several genetic studies have shown that the Ainu and the recent northeast Asian populations share some characteristics (Cavalli-Sforza et al., 1988; Matsumoto, 1987; Harihara et al., 1992). Although the origin of the Jomon-Ainu remains elusive (Yamaguchi, 1992), it is difficult to accept the Jomon-Pacific cluster proposed by Brace and his coworkers.

The peoples of the Marianas and Polynesia share some common genetic characteristics and usually cluster in genetic distance analyses (Cavalli-Sforza et al., 1988; Nei and Roychoudhury, 1993), although the extent of their similarity varies with the kind of genetic data used (Serjeantson, 1989; Hill et al., 1989; O'Shaughnessy et al., 1990). As mentioned above, the present study demonstrates almost the same clustering. However, the Mariana skeletons are quite different in facial flatness and limb bone morphology from those of the Polynesians (Ishida, 1992, 1993). Katayama (1986) found morphological variation in the postcranial skeleton among the Polynesians based on his examination of the skeletal series from the Cook Islands. Howells (1990) has indicated that genetic drift could be responsible for this Polynesian and Marianan differentiation. Furthermore, the greater variation in the skeletal morphology of the Pacific peoples may be due to adaptation to their perspective life activities and environments.

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LITERATURE CITED

Becker RA, Chambers JM, and Wilks AR (1988) The New S Language. Pacific Grove, CA: Wadsworth & Brooks.

Bellwood PS (1989) The colonization of the Pacific: Some current hypotheses. In AVS Hill and SW Serjeantson (eds.): The Colonization of the Pacific, A Genetic Trail. Oxford: Clarendon, pp. 1–59.

Brace CL, and Hinton RJ (1981) Oceanic tooth-size variation as a reflection of biological and cultural mixing. Curr. Anthropol. *22:*549–569.

Brace CL, Brace ML, Dodo Y, Hunt KD, Leonard WR, Li Y, Sangvichien S, Xiang-qing S, and Zhenbiao Z (1990) Micronesians, Asians, Thais and relations: A craniofacial and odontometric perspective. Micronesica (Suppl.) *2:*323–348.

Brace CL and Tracer DP (1992) Craniofacial continuity and change: A comparison of late Pleistocene and recent Europe and Asia. In T Akazawa, K Aoki, and T Kimura (eds): The Evolution and Dispersal of Modern Humans in Asia. Tokyo: Hokusen-sha, pp. 439–471.

Cavalli-Sforza LL, Piazza A, Menozzi P, and Mountain J (1988) Reconstruction of human evolution: Bringing together genetic, archaeological, and linguistic data. Proc. Natl. Acad. Sci. U.S.A. *85:*6002–6006.

Dodo Y (1974) Non-metrical cranial traits in the Hokkaido Ainu and the northern Japanese of recent times. J. Anthropol. Soc. Nippon *82:*31–51.

Dodo Y (1986a) A population study of the jugular foramen bridging of the human cranium. Am. J. Phys. Anthropol. *69:*15–19.

Dodo Y (1986b) Nonmetric cranial variants of the Micronesians from Guam. In K Hanihara (ed.): Anthropological Studies on the Origin of Pacific Populations, with Special Reference to the Micronesians—A Preliminary Report. Grant-in-Aid for Overseas Scientific Surveys, Ministry of Education, Japan, pp. 58–65.

Dodo Y (1986c) Metrical and non-metrical analyses of Jomon crania from eastern Japan. In T Akazawa and CM Aikens (eds.): Prehistoric Hunter-Gatherers in Japan. Tokyo: University of Tokyo Press, pp. 137–161.

Dodo Y (1986d) A study of the facial flatness in several cranial series from East Asia and North America. J. Anthropol. Soc. Nippon *94:*81–93.

Dodo Y (1987) Supraorbital foramen and hypoglossal canal bridging: The two most suggestive nonmetric cranial traits in discriminating major racial groupings of man. J. Anthropol. Soc. Nippon *95:*19–35.

Dodo Y (1994) The origin of Japanese: A nonmetric cranial approach. J Clin. Exp. Med. *169:*886–888. (in Japanese)

Dodo Y, and Ishida H (1990) Population history of Japan as viewed from cranial nonmetric variation. J. Anthropol. Soc. Nippon *98:*269–287.

Doi N, and Tanaka Y (1987) A geographical cline in metrical characteristics of Kofun skulls from western Japan. J. Anthropol. Soc. Nippon *95:*325–343.

Gao X, and Serjeantson SW (1991) Diversity in HLA-DR4-related DR,DQ haplotypes in Australia, Oceania, and China. Hum. Immunol. *32:*269–276.

Gao X, and Serjeantson SW (1992) Twelve HLA-DR6-related DRB1 alleles and associated DR,DQ haplotypes in traditional Australians and other populations of Asia-Oceania. Eur. J. Immunogen. *19:*263–272.

Hanihara T (1992) Dental and cranial affinities among populations of East Asia and the Pacific: The basic

population in East Asia, IV. Am. J. Phys. Anthropol. *88:*163–182.

Hanihara T (1993) Population prehistory of East Asia and the Pacific as viewed from craniofacial morphology: The basic populations in East Asia VII. Am. J. Phys. Anthropol. *91:*173–187.

Harihara S, Hirai M, Suutou Y, Shimizu K, and Omoto K (1992) Frequency of a 9-bp deletion in the mitochondrial DNA among Asian populations. Hum. Biol. *64:* 161–166.

Hill AVS, O'Shaughnessy DF, and Clegg JB (1989) Haemoglobin and globin gene variants in the Pacific. In AVS Hill and SW Serjeantson (eds): The Colonization of the Pacific, A Genetic Trail. Oxford: Clarendon, pp. 246–285.

Howells WW (1973) Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Difference among Recent Human Populations. Papers of the Peabody Museum of Archaeology and Ethnology, 67. Cambridge, MA: Harvard University Press.

Howells WW (1979) Physical anthropology. In JD Jennings (ed.): The Prehistory of Polynesia. Cambridge, MA: Harvard University Press, pp. 271–285.

Howells WW (1989) Skull Shapes and the Map. Papers of the Peabody Museum of Archaeology and Ethnology, 79. Cambridge, MA: Harvard University Press.

Howells WW (1990) Micronesia to Macromongolia: Micro-Polynesian craniometrics and the Mongoloid population complex. Micronesica (Suppl.) *2:*363–372.

Ishida H (1992) Flatness of facial skeletons in Siberian and other circum-Pacific populations. Z. Morphol. Anthropol. *79:*53–67.

Ishida H (1993) Limb bone characteristics in the Hawaiian and Chamorro peoples. Jpn. Rev. *4:*45–57.

Ishida H, and Dodo Y (1993) Nonmetric cranial variation and the populational affinities of the Pacific peoples. Am. J. Phys. Anthropol. *90:*49–57.

Ishida H, and Dodo Y (1996) Cranial morphology of the Siberians and East Asians. In T Akazawa and EJE Szathmary (eds.): Prehistoric Dispersal of Mongoloids. Oxford: Oxford University Press, pp. 113–124.

Katayama K (1986) Human skeletal remains of late pre-European period from Mangaia, Cook Islands. Man and Culture in Oceania *2:*57–80.

Katayama K (1987) Physical anthropology in Polynesia: Japanese contribution. Man and Culture in Oceania *3* (Special Issue):1–18.

Katayama K (1988) A comparison of the incidences of non-metric cranial variants in several Polynesian populations. J. Anthropol. Soc. Nippon *96:*357–369.

Katayama K (1990) A scenario on prehistoric Mongoloid dispersals into the South Pacific, with special reference to hypothetic Proto-Oceanic connection. Man and Culture in Oceania *6:*151–159.

Konigsberg LW (1990) Analysis of prehistoric biological variation under a model of isolation by geographic and temporal distance. Hum. Biol. *62:*49–70.

Li Y, Brace CL, Gao Q, and Tracer DP (1991) Dimensions of face in Asia in the perspective of geography and prehistory. Am. J. Phys. Anthropol. *85:*269–279.

Matsumoto H (1987) Characteristics of the Mongoloid and neighboring populations on the basis of the genetic markers of immunoglobulins. J. Anthropol. Soc. Nippon *95:*291–304. (in Japanese)

Matsumura H (1994) A microevolutional history of the Japanese people from a dental characteristics perspective. Anthropol. Sci. *102:*93–118.

Mizoguchi Y (1988) Affinities of the protohistoric Kofun people of Japan with pre- and protohistoric Asian populations. J. Anthropol. Soc. Nippon *96:*71–109.

Nakahashi T (1993) Temporal craniometric changes from the Jomon to the modern period in western Japan. Am. J. Phys. Anthropol. *90:*409–425.

Nei M, and Roychoudhury AK (1993) Evolutionary relationships of human populations on a global scale. Mol. Biol. Evol. *10:*927–943.

Omoto K (1985) The negritos: genetic origins and microevolution. In R Kirk and EJE Szathmary (eds.): Out of Asia, Peopling the Americas and the Pacific. Canberra: Journal of Pacific History, pp. 123–131.

Ossenberg NS (1986) Isolate conservatism and hybridization in the population history of Japan: The evidence of nonmetric cranial traits. In T Akazawa and CM Aikens (eds.): Prehistoric Hunter-Gatherers in Japan. Tokyo: University of Tokyo Press, pp. 199–215.

Pietrusewsky M (1971) Human skeletal remains at Anaehoomalu. Department of Anthropology, Report 71-7. Honolulu: Bernice P. Bishop Museum, pp. 1–78.

Pietrusewsky M (1984) Metric and non-metric cranial variation in Australian Aboriginal populations compared with populations from the Pacific and Asia. Occasional Papers in Human Biology *3:*1–113. Canberra: Australian Institute of Aboriginal Studies.

Pietrusewsky M (1989) A Lapita-associated skeleton from Natunuku, Fiji. Records of the Australian Museum *41:*297–325.

Pietrusewsky M (1990a) Craniometric variation in Micronesia and the Pacific: A multivariate study. Micronesica (Suppl.) *2:*373–402.

Pietrusewsky M (1990b) Craniofacial variation in Australian and Pacific populations. Am. J. Phys. Anthropol. *82:*319–340.

Pietrusewsky M (1992) Taiwan aboriginals, Asians and Pacific Islanders: A multivariate investigation of skulls. Taipei, Paper to be presented at the International Symposium on Austronesian Studies Relating to Taiwan.

Pietrusewsky M (1994) Pacific-Asian relationships: A physical anthropological perspective. Oceanic Linguistics *33:*407–429.

Pietrusewsky M (1997) The people of Ban Chiang: An early Bronze site in Northeast Thailand. Chiang Mai, Proceedings of the Indo-Pacific Prehistoric Association *16:*119–148.

Saitou N, and Nei M (1987) The neighbor-joining method: A new method for reconstructing phylogenetic trees. Mol. Biol. Evol. *4:*406–425.

Serjeantson SW (1989) HLA genes and antigens. In AVS Hill and SW Serjeantson (eds.): The Colonization of the Pacific, A Genetic Trail. Oxford: Clarendon, pp. 120–173.

Sneath PHA, and Sokal RR (1973) Numerical Taxonomy. San Francisco: WH Freeman.

Turner CG II (1976) Dental evidence on the origins of the Ainu and Japanese. Science *193:*911–913.

Turner CG II (1987) Late Pleistocene and Holocene population history of East Asia based on dental variation. Am. J. Phys. Anthropol. *73:*305–321.

Turner CG II (1989) Teeth and prehistory in Asia. Sci. Am. *260:*70–77.

Turner CG II (1990) Major features of sundadonty and sinodonty, including suggestions about East Asian microevolution, population history, and late Pleistocene relationships with Australian Aboriginals. Am. J. Phys. Anthropol. *82:*295–317.

Yamaguchi B (1973) Facial flatness measurements of the Ainu and Japanese crania. Bull. Natl. Sci. Mus. Tokyo *16:*161–171.

Yamaguchi B (1980) A study on the facial flatness of the Jomon crania. Bull. Natl. Sci. Mus. Tokyo Series D (Anthropology) *6:*21–28.

Yamaguchi B (1982) A review of the osteological characteristics of the Jomon population in prehistoric Japan. J. Anthrop. Soc. Nippon *90* (Suppl.):77–90.

Yamaguchi B (1992) Skeletal morphology of the Jomon people. In K Hanihara (ed.): Japanese as a Member of the Asian and Pacific Populations. Kyoto: IRCJS Press, pp. 53–63.